XXVI. *An Account of ſome new Experiments on the Production of artifical Cold. In a Letter from* Thomas Beddoes, *M. D. to Sir* Joſeph Banks, *Bart. P. R. S.*

Read May 10, 1787.

DEAR SIR, Oxford, May 2, 1787.

MR. WALKER, Apothecary to the Radcliffe Infirmary here, has been engaged upwards of a year in a ſeries of experiments on the means of producing artificial cold, ſeveral of which ſeem to me to be very remarkable, and ſuch as, conſidering their novelty, and the attention which has lately been paid to this ſubject, I flatter myſelf, will be found to deſerve a place among the Tranſactions of the Society over which you preſide.

Mr. WALKER, in his firſt experiments, found, as BOERHAAVE had done before him, that ſal ammoniac, as well as nitre, well dried in a crucible, and reduced to a fine powder, will produce a greater degree of cold than if they had not received this treatment. But BOERHAAVE, by ſal ammoniac, lowered the temperature of water only by 28°; whereas Mr. WALKER obſerved his thermometer to fall 32°, and when he uſed nitre 19°. It occurred to him, that the combination of theſe ſubſtances would produce a greater effect than either ſeparately: and he found that this was really the caſe. A propoſal for freezing water in ſummer, mentioned by Dr. WATSON (Eſſays, III. 139.) determined him to attempt the ſame thing

thing in this way. Accordingly, April 28, 1786, the thermometer ſtanding at 47°, he made a ſolution of a powder, conſiſting of equal parts of ſal ammoniac and nitre, in a baſon, by means of which he cooled ſome water, contained in a glaſs tumbler, to 22°. To this he added ſome of the ſame powder, and immerſed two very ſmall phials in it; one containing boiled, the other unboiled water; when he ſoon found the water in the phials to be frozen, the unboiled freezing firſt.

Having obſerved that GLAUBER's ſalt, when it retains its water of cryſtallization, produces cold during its ſolution, he thought of adding this to his other powers, and July 18, 1786, reduced the thermometer 46 degrees. In this experiment the following proportions were uſed: the temperature of the air being 65°, to water four ounces, at 63°, were added,

Of ſal ammoniac ℥ xi	thermometer ſunk to	32°, that is,	31°
Of nitre ℥ x	- - -	24°, that is,	8°
Of GLAUBER's ſalts ℥ ij	- -	17°, that is,	7°
			46°

In this way he froze water on a day ſo hot that the thermometer in the ſhade ſtood at 70°. By firſt cooling the ſalts and water in one mixture, and then making another of theſe cooled materials, he ſunk the thermometer 64 degrees.

Auguſt 28. The temperature of the air being 65°, half an ounce of rectified ſpirit of wine was diluted with three ounces and an half of water, and immerſed in the ſame frigorific mixture. When cooled to 24°, it began to freeze. A quantity of the neutral ſalts, likewiſe cooled in the mixture, were put into the diluted ſpirit, when the thermometer fell to −4°, ſo that the liquor was cooled 69 degrees.

Spirit of nitre, diluted in the manner deſcribed by Mr. CAVENDISH (Phil. Tranſ. vol. LXXVI. part I.), having reduced the thermometer to $-3°$, ſal ammoniac was added, upon which it fell to $-15°$.

Nitrated volatile alkali, during its ſolution in water, reduced the thermometer 35 degrees (from 50° to 15°); but the cold was not increaſed by ſal ammoniac or nitre.

Mr. WALKER's moſt remarkable experiment was made on the 21ſt of March, 1787, when he found that nitrous acid, when poured upon GLAUBER's ſalt, produced effects nearly the ſame as when it is poured on pounded ice; and that the cold, thus produced, is rendered ſtill more intenſe by the addition of ſal ammoniac in powder.

Mr. WALKER, by many trials, diſcovered that the beſt proportion of theſe ingredients is the following: of concentrated nitrous acid, 2 parts by weight, of water 1 part; of this mixture cooled to the temperature of the atmoſphere eighteen ounces, of GLAUBER's ſalt a pound and an half (avoirdupois), and of ſal ammoniac twelve ounces. On adding the GLAUBER's ſalt to the nitrous acid, thus diluted, the thermometer fell from $+51°$ to $-1°$, or 52 degrees; and on adding the ſal ammoniac it fell to $-9°$, that is full 60 degrees. Nitrated volatile alkali, employed inſtead of ſal ammoniac, produced a cold rather more intenſe.

By means of this mixture, in a very few minutes, in the elaboratory before the claſs, I froze ſome ſpirits above proof, diluted with an equal bulk of water; and another gentleman this day ſunk the thermometer 68 degrees.

On April 20, 1787, Mr. WALKER effected the congelation of quickſilver by a combination of theſe mixtures, without a particle of ſnow or ice. When he began his experiment the temperature

temperature of the mercury was 45°, ſo that, the freezing point of that metal being − 39°, there were produced 84 degrees of cold.

This experiment was performed as follows. Four pans, of ſizes progreſſively diminiſhing, ſo that one might be placed within the other, were procured. The largeſt of theſe pans was placed in another veſſel ſtill larger, in which the materials for the ſecond frigorific mixture were thinly ſpread, in order to be cooled. The ſecond pan, containing the liquor (*viz.* vitriolic acid, properly diluted) was placed in the largeſt pan. The third pan, containing the ſalts for the third mixture, was immerſed in the liquor of the ſecond pan; and the liquor for the third mixture was put into wide-mouthed phials, which were immerſed in the ſecond pan likewiſe, and floated round the third pan. The fourth pan, which was the ſmalleſt of all, containing its cooling materials, was placed in the midſt of the ſalts of the third pan.

Of the materials for the mixtures to be made in theſe four pans, the firſt and ſecond conſiſted of diluted vitriolic acid and GLAUBER's ſalt, the third and fourth of diluted nitrous acid, GLAUBER's ſalt and ſal ammoniac, in the proportions aſſigned.

The pans being adjuſted in the manner above deſcribed, the materials of the firſt and largeſt pan were mixed: this mixture reduced the thermometer to + 10, and cooled the liquor in the ſecond pan to + 20; and the ſalts for the ſecond mixture, which were placed underneath in the large veſſel, nearly as much. The ſecond mixture was then made with the materials thus cooled, and it reduced the thermometer to 3°. The ingredients of the third mixture, by immerſion in this, were cooled to + 10°, and when mixed reduced the thermometer to − 15°. The materials for the fourth mixture were cooled by immerſion in this third mixture to about − 12°. On mixing they made the mercury in the thermometer ſink rapidly, and as it

appeared to Mr. WALKER, below $-40°$. Its thread ſeemed to be divided below that point; but the froth occaſioned by the ebullition of the materials prevented his making ſo accurate an obſervation as he could have wiſhed.

The reaſon why this laſt mixture reduced the thermometer more than the third, though both were of the ſame materials, and the laſt at a lower temperature, Mr. WALKER imagines to have been partly becauſe the fourth pan had not another immerſed in it to give it heat, and partly becauſe the materials were reduced to a finer powder.

I ſhould imagine, that mercury reduced to its freezing point will freeze more quickly than water reduced to its freezing point, becauſe it appears, from experiments on their capacity for heat, that the latter of theſe bodies has ſo much more latent heat in its liquid ſtate; which greater quantity of latent heat muſt, as it becomes ſenſible, more retard the congelation.

I forbear to enumerate many variations of theſe experiments which Mr. WALKER has among his notes; but there is one mixture which, though its power is not equal to that which I have laſt deſcribed, may prove very ſerviceable in experiments of this nature, on account of its cheapneſs. It conſiſts of oil of vitriol diluted with an equal weight of water: added to GLAUBER's ſalt, it produces about 46 degrees of cold. The addition of ſal ammoniac renders it more intenſe by a few degrees. One remarkable circumſtance occurred to Mr. WALKER, as he was endeavouring to aſcertain the beſt ſtrength of the vitriolic acid: he happened to be trying a mixture of two parts of oil of vitriol and one of water, when he obſerved, that, at the temperature of $35°$, the mixture coagulated as if frozen, and the thermometer became ſtationary; but, on adding more GLAUBER's ſalt, it fell again, after ſome little time, but ſo great a

cold was not produced as when this circumſtance did not occur, and when the acid was weaker. The ſame appearance of congelation took place with other proportions of acid and water, at other temperatures.

Mineral alkali, when it retained its water of cryſtallization, added to ſome of theſe mixtures heightened their effects. But when it had loſt this water, it rather produced heat than cold; and the ſame thing is alſo true of GLAUBER's ſalt. This circumſtance leads us, in ſome meaſure, to the theory of theſe phænomena. Water undoubtedly exiſts in a ſolid ſtate in cryſtals; it muſt therefore, as in other caſes, abſorb a determinate quantity of fire, before it can return to its liquid ſtate. On this depends the difference between GLAUBER's ſalt and foſſil alkali in their different ſtates of cryſtallization and efflorescence. The ſame circumſtance too enables us to underſtand the great effect of GLAUBER's ſalt, which, as far as I recollect, has the greateſt quantity of water of cryſtallization.

Thoſe, therefore, who ſhall chooſe to purſue the path which Mr. WALKER has opened to them, would do well to try combinations of ſalts containing much water of cryſtallization; but they muſt take care leſt the effect ſhould be diminiſhed or deſtroyed by the formation of compounds that fix a ſmaller quantity of fire. It is, however, but juſtice to Mr. WALKER to obſerve, that he has carried his experiments in this way very far, and with great ingenuity.

I have the honour to be, &c.

THOMAS BEDDOES.